Developing a National Stock Model to Support Building Energy Efficiency Research and Policy in Egypt

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Abstract: In Egypt, the building sector is responsible for 60% total electricity consumption and around 70% of resultant CO_2 emissions. Due to the growing population, a high rate of rural electrification, increased use of electrical appliances and the "heat island effect" exacerbating overheating in major urban centers, the residential sector has become the main consumer of electricity in the country. Following the recent spate of power blackouts, government policy has attempted to reduce peak electricity demand through the introduction of various measures, highlighting the improvement of the efficiency of the building stock as a significant contributor to achieving this aim.

To support this goal, there is a need to develop a comprehensive physics-based energy use model for the Egyptian residential building stock to estimate the baseline energy consumption and provide insight on the future of its energy demand. In addition, the model can be used to assess the environmental and socio-economic impacts of micro-renewable energy technologies and fabric upgrade solutions that reduce energy demand while maintaining lifestyle, health and comfort.

This paper will present a framework for the development of an Egyptian Domestic Energy Model (EDEM) supported by a representative database of building stock archetypes. The scope and functionality of the model are presented and the envisaged overarching structure and components are illustrated. In addition, new and existing data sources (such as the CAPMAS Egyptian Housing Survey) that could be used to populate the underlying databases of this model are discussed.

Keywords: *Energy Efficiency, Residential Sector, Stock Model*

1. Energy Consumption Trends in Egypt

In the period leading up to the 2011 revolution, Egypt witnessed a trend in sustained economic growth. As with many developing economies, despite having one of the lowest installed electricity generation capacity levels per capita in the Middle East (under 500 Watts per person), this triggered a rapid increase in the per capita energy consumption. Between 1990–2006, the average annual growth rate of energy consumption per capita reached 2.34%, closely following the average annual growth rate of real GDP per capita which reached 2.27% [1].

In an attempt to keep up with the growing trend in total consumption and peak demand, both the total generation and peak generating capacity have also grown steadily (Figure 1). It was thought that an 8% margin was maintained between the installed electricity capacity (the maximum power that can be generated at one time) and peak load (the maximum electricity demand level). However, the recent spate of power cuts and blackouts in the summer of 2012 have raised concerns of a systemic electricity capacity shortage and have had substantial economic, political and social impacts. For example, frequent power outages result in significant losses for enterprises and manufacturing in forgone sales and damaged equipment [2].

An examination of recent electricity production and use statistics highlight three key issues; firstly, nominal generation capacity is less than summer peak demand and, secondly, peak electricity demand has increased by more than 300% between 1992 and 2011 and finally, the customer base using what electricity is generated has increased five-fold in the past two decades.
The implementation of an integrated strategy that combines both relevant

technical and policy options that strive to reduce energy demand in the various socio-economic sectors [3] can help provide secure, reliable and affordable energy services that are fundamental to economic stability and development. In addition, this can also help to avoid the issues resulting from rising energy demand and electricity peak loads such as the 2012 blackouts [4].

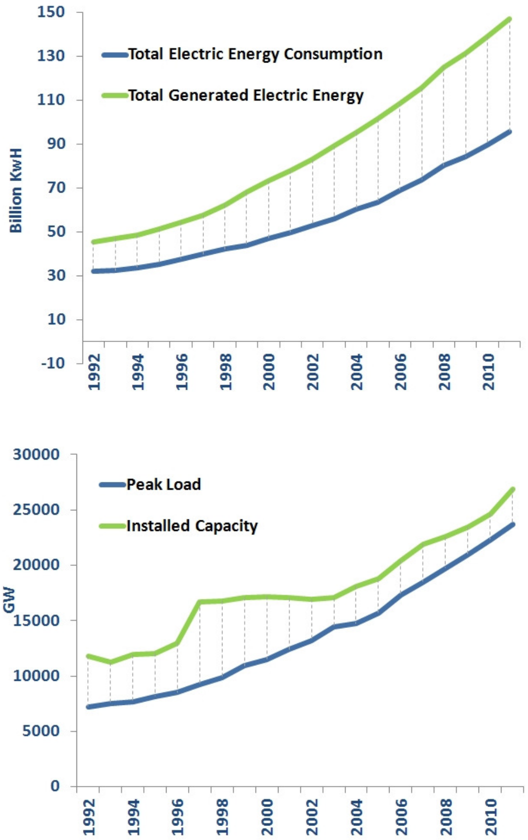


Fig.1. Electricity consumption/generation & peak load/installed capacity trends in Egypt 1992-2011[5]

1.1. *The Egyptian Building Sector: Challenges and Opportunities*

On a global scale, the built environment is the largest part of the physical and economic human-made capital [6], where the construction sector itself constitutes a major part of the gross national product (GNP) [7] and accounts for 40% of the world's resource and energy use [8]. In Egypt, the sector is a particularly significant contributor to the economy (averaging at 25% of the GNP) [9] and is also a key user of energy. It is thought that the built environment in Egypt is responsible for 26% of the total overall national energy consumption, 62% of the total electricity consumption and around 70% of resultant CO_2 emissions [10]. It is therefore imperative that the sector be considered a key target of energy consumption policies.

In recent years, due to the growth of the consumer base, a high rate of rural electrification, increased use of electrical appliances and the Urban Heat Island effect (UHI) afflicting major urban centres, the domestic building sector, in particular, has become the main consumer of electricity in the country, accounting for 47% of the electricity consumed and 23% of the total energy consumption (Figure 2).

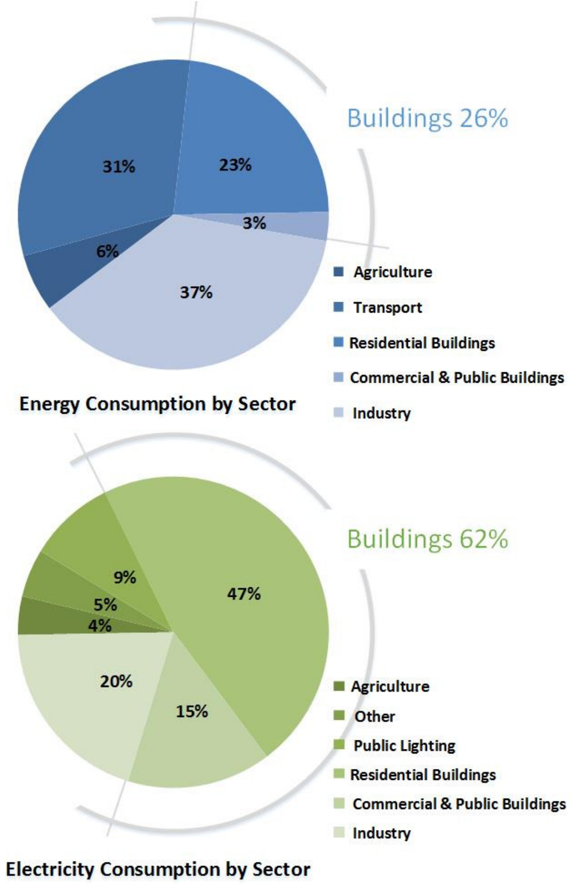


Fig.2. Contribution of the building sector to the energy and electricity consumption in Egypt: 2005-2006 estimates [5,11]

Furthermore, as an unintended consequence of both global and local climate change, the sector has seen a marked increase in the usage of electricity-consuming cooling and refrigeration devices. For example, the use of air conditioning (AC) units has increased dramatically over the 13-year period from 1999-2012. Official figures indicate that the number of AC units rose from 196,000 in 1999 to three million in 2009, and then doubled to six million units by 2012. In addition to accounting for 20% of energy consumption, the use of these devices also in turn worsens the UHI through the release of waste heat into urban canyons.

In recognition of the importance of the building sector, the government has highlighted the efficiency improvements in of the building stock as a significant contributor to achieving energy and emissions reduction targets. Even though government strategy has, to date, mainly focused on behavioural change approaches, a more holistic approach that integrates a plethora of available technical and policy options should be adopted [12]. The various instruments which fall under these two broad categories can be described as:
- Technical options: These include a wide array of energy efficient design practices and technology-based approaches that mainly involve the reduction of energy demand through the improvement of fabric efficiency and the installation of efficient equipment, appliances and lighting. Despite the effectiveness of technical options, it has been recognised that factors such as financial hurdles, hidden costs and benefits, market failures and behavioural constraints often inhibit their uptake [13,14].
- Policy options: Key policy instruments include control and regulatory instruments, economic/market-based instruments, financial instruments/incentives, and support, information and voluntary action (e.g. [15–17]. In Egypt, the main domestic energy code was completed in 2003 and followed by a commercial energy code in 2005 [18].

2. Overview of Stock Modelling

Modelling can be described as the process of developing a model that faithfully represents a complex system [19], of which buildings are one type. With regard to the estimation of the energy consumption and the objective assessment of the energy performance of buildings, various physics-based modelling techniques exist ranging from simple energy balance models to detailed dynamic simulation models.

In response to the growing demand for tools to support the analysis of energy use in the building stock over time [20], several physics-based domestic stock energy models have been developed in order to estimate the baseline energy consumption of the existing stock as well as to provide insight into the future of its energy demand [21]. The broad aim of these models is to provide an understanding of the complex interactions between specific physical, social or economic variables and household energy use [22].

2.1. Modelling Approaches: Bottom-Up vs Top-Down

The IEA defines two fundamental classes of modelling methods used to predict and analyse various aspects of building stock energy consumption and associated emissions: the *top-down* and *bottom-up* approaches [23].

2.1.1. Top-down methods

These work at an aggregated level and typically aim to fit a historical time series of national energy consumption or emissions data. Models employing the top-down method can be broadly categorised as econometric and technological and are mainly used to investigate the inter-relationships between the energy sector and the economy at large [21,24].

2.1.2. Bottom-up methods

These build up from data on a hierarchy of disaggregated components. These are then combined based on an estimate of their individual impact on energy usage [25]. Through the combination of building physics, empirical data (e.g. housing surveys) and assumptions concerned with building operation, bottom-up based models allow the estimation of energy consumption in the housing stock.

2.2. Model Complexity: Simple vs Dynamic

Stock modelling utilises an energy calculation method as a core calculation engine to estimate the delivered energy consumption of the building stock studied. The model's complexity is, in part, determined by the type of core calculation engine used [21] which can be broadly defined as either simple or dynamic/ complex.

2.2.1. Simple calculation cores

The term 'simple' denotes that certain assumptions are applied to the underlying model, where some energy or mass flow paths that interact in a dynamic fashion may either be approximated or entirely omitted [19]. Approaches such as the simple degree-day method, developed degree-day method or the monthly heat balance (utilisation factor) method [26] are used and variables are averaged over a longer period (monthly, seasonally or annually) [27]. Due to their simplicity, speed of execution and ease of use, simplified calculation cores are widely used for stock modelling applications. One of the most widely known of these is BREDEM (The Building Research Establishment's Domestic Energy Model) which was developed in the UK and employs series of heat balance equations and empirical relationships to produce an estimate of the annual or monthly energy consumption [28,29].

2.2.2. Complex Dynamic Simulation Methods

These involve the implementation of complex and iterative predictive (typically hourly) analytical procedures [30]. The tools that use this approach enable the study of the transient responses of a building and its energy systems to the climate [31] and allow the specification of detailed parameters that influence building performance. While this approach is generally considered to be more realistic and accurate and more suitable for the study of thermal mass effects, potential issues such as slow calculation/ execution speeds and resultant model complexity must be considered.

3. The development of an Egyptian Domestic Energy Model (EDEM)

While regional projects, programs and initiatives have aimed to promote and increase the energy efficiency of buildings through, this has been hampered by limited coordination of efforts and accumulation of gained experience as well as the lack of information available for estimating such aspects as fabric performance and space cooling loads and their influence on the electric load profile [32,33].

Recent research highlighting the need for validated data has aimed to produce benchmark models for the Egyptian domestic sector, leading to the development of two building performance simulation models designed to reflect the average energy consumption characteristics of air-conditioned residential apartments in three main urban areas [32].

To encourage the uptake of energy efficiency measures in the Egyptian building sector, it is important that a wide-scale national program be developed and implemented. As such, to support this goal, there is a need to extend current research to the development of a more comprehensive and flexible physics-based energy use model for the Egyptian domestic building stock. To meet this need, an Egyptian Domestic Energy Model (EDEM) is proposed with the overall aim of providing useful insights in support of plans for the delivery of a more efficient domestic stock

[20]. In terms of application, it is envisioned that the model would be able to undertake the following key functions:

- To estimate the baseline energy demand of the existing domestic stock and provide insight on the future of its energy demand.
- To explore the technical and socio-economic effects of different reduction strategies and energy efficiency upgrades over time, including the impact of new technologies and building materials as well as renewable energy solutions.
- To estimate the technical and economic potential for the deployment of specific new technologies and building materials as well as micro-distributed renewable energy solutions.
- To explore the impacts and unintended consequences of reduction strategies and energy efficiency upgrades on the internal environment and associated impacts on occupant comfort and health.

In developing the scope and functionality of EDEM, the key criteria outlined by Coffey *et al* [20], regarded as important in shaping the model structure as well as its implementations, were considered. These include the ability to ask a variety of *'what if'* questions through the provision of flexibility in the model structure and interfaces, the transparency of assumptions and facilitation of user interactivity and the provision of support for uncertainty and sensitivity analysis.

3.1. Model Description, Overarching Structure and Components

The proposed EDEM model will be based on the aforementioned bottom-up modelling approach. A physics-based calculation engine will be used to determine the energy demand of individual buildings representative of the whole building stock, which will then be weighted to give an overall estimate of the energy demand of the domestic stock. The envisaged model framework is illustrated in Figure 3 and its main components can be summarized as follows:

- **Model Data Module:** The framework for the integration and updating of the information highlighted in 3.1.3 Data Sources in the form of model databases
- **Base Model Execution Module:** The main implementation of the baseline stock calculation, with added functionality for sub-sample selection.
- **Scenarios Module:** This will allow the variation of base input assumptions to allow for the exploration of the impacts of various changes to the building stock and fuel prices etc.
- **Output Module:** The main output interface for the model.

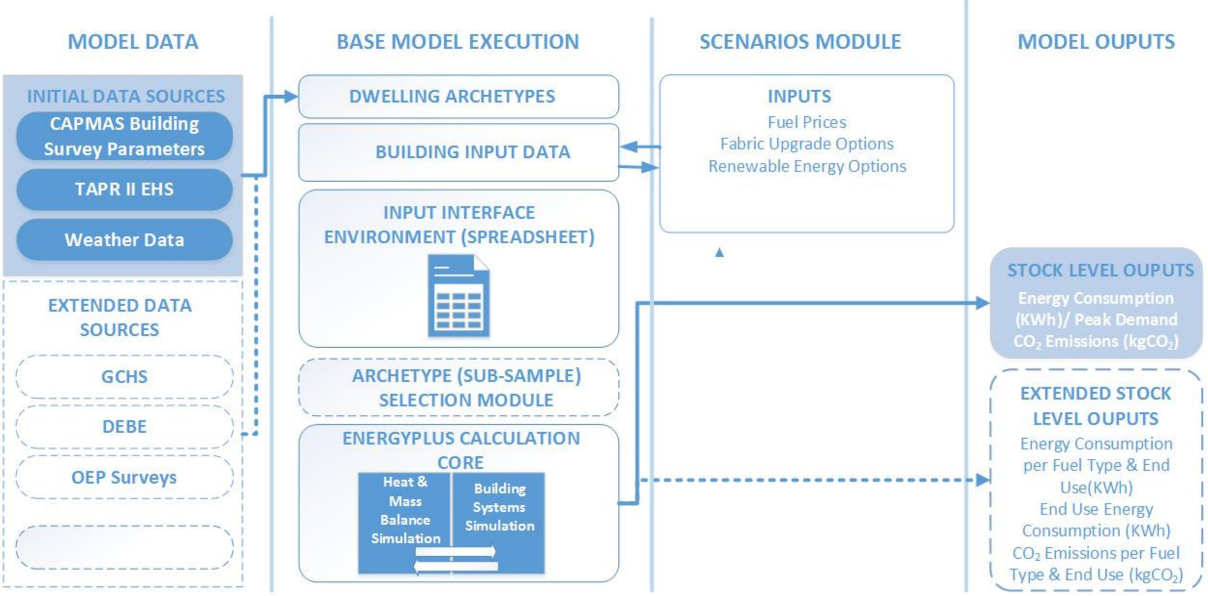

MODEL DATA
BASE MODEL EXECUTION
SCENARIOS MODULE
MODEL OUPUTS
INITIAL DATA SOURCES
CAPMAS Building Survey Parameters
TAPR II EHS
Weather Data
EXTENDED DATA SOURCES
GCHS
DEBE
OEP Surveys
DWELLING ARCHETYPES
BUILDING INPUT DATA
INPUT INTERFACE ENVIRONMENT (SPREADSHEET)
ARCHETYPE (SUB-SAMPLE) SELECTION MODULE
ENERGYPLUS CALCULATION CORE
Heat & Mass Balance Simulation
Building Systems Simulation
INPUTS
Fuel Prices
Fabric Upgrade Options
Renewable Energy Options
STOCK LEVEL OUPUTS
Energy Consumption (KWh)/ Peak Demand
CO2 Emissions (kgCO2)
EXTENDED STOCK LEVEL OUPUTS
Energy Consumption per Fuel Type & End Use(KWh)
End Use Energy Consumption (KWh)
CO2 Emissions per Fuel Type & End Use (kgCO2)

Fig.3. EDEM Overarching Structure and Components

3.1.1. Modelling Calculation Engine

The choice of core model for EDEM was in the first instance based on the consideration of the advantages and disadvantages of the simple and complex methods described. In addition, such factors as the requirements of potential the model user base and the practical feasibility of achieving them were analysed in the decision-making process. As a result, it is envisioned that EDEM will be based around a complex calculation core developed by the US Department of Energy, EnergyPlus (current version 7.2.0) [34].

EnergyPlus is a complex tool based on systems simulation modules integrated with a heat balance-based zone simulation in which analysis is performed at time steps of less than an hour. As a multi-platform, open source tool, EnergyPlus has been extensively validated.

Furthermore, various licensing options that address the needs of both commercial and non-commercial uses and allow for various degrees of ownership of derivative works and redistribution rights exist are available, which will be essential for the continued development of EDEM [34].

In terms of applicability, the software has already been used for a number of stock level applications. Examples of these include its use as the calculation core for a UK non-domestic energy stock model [35] as well as the development of a complex domestic stock model applied to research the hygrothermal performance of dwellings in the London area [25].

3.1.2. Model Interfaces

While EnergyPlus uses a standard default non-graphical user interface (IDF Editor) a recent free to the end user graphical user interface (SIMERGY) [36] has been developed. The input and output data structures of EnergyPlus also facilitate the development of more user-friendly (and domain-specific) third party interfaces.

For EDEM, a 'function specific' input interface will need to be developed to allow for the handling of the extensive databases associated with stock modelling. During the initial development phases, it is expected that this will involve the use of an excel-based input spreadsheet, primarily designed as a simple non-graphical input format for information that will then be translated into the *.idf format required to run the EnergyPlus calculation core. Initial handling of output data will follow a similar approach and involve the post processing of *.csv outputs via macro-enabled spreadsheets.

Further development of the interface will include the investigation into the incorporation of the graphical capabilities provided by SIMERGY, which is currently available to download as a Beta version. In addition, the development of a combined input/output configuration for the interface will also be investigated.

3.1.3. Data Sources

The identification of data sources that can be used to populate the underlying databases of any model is integral to the model development process. Based on a review of relevant literature in the field as well as available government databases and census data, a number of key data sources can be identified for EDEM. These data sources and a brief description of their contents are listed in Table 1.

It is important to note that as with any data collection process, certain limitations apply to the information contained in the listed databases. For example, certain surveys were undertaken a number of years ago (pre-dating the era of rapid development in the New Cairo suburban areas among others) and other surveys only cover a small sample size in limited locations.

Table 1 Key Data Sources for EDEM

Source	Description
Central Agency for Public Mobilization and Statistics (CAPMAS) [11]	Statistical census information from 1996 and 2006 covering a Governorate level breakdown of housing typologies, age bands, tenure…etc.
Organisation for Energy Planning (OEP) and Cairo University Survey [37]	A domestic energy survey conducted in 1998 on a sample of 2634 flats covering 16 zones in Greater Cairo.
Organisation for Energy Planning (OEP): Port Said and Alexandria Surveys [38,39]	A series of surveys conducted in 2001 and 2002 in Port Said (sample size: 926 flats), Alexandria (sample size: 2750 flats)
Organisation for Energy Planning (OEP) and Asyut University Survey [40]	An energy consumption survey conducted in 2001 and 2002 on a sample of 807 flats in 13 different districts of Asyut.
Database Of Egyptian Building Envelopes (DEBE) [41]	A database of envelope component sections representative of the region.
Egypt Benchmark Models (EBM) [32]	Two simulation models designed to reflect the average energy consumption characteristics of air-conditioned flats in three urban areas
Technical Assistance for Policy Reform II Housing Survey (TAPR II EHS)[42]	Survey data collected in May and June 2008. Number of PSUs = 1079. Sample size = 21,580 households living in 17,852 buildings.
Greater Cairo Housing Survey (GCHS)[43,44]	A survey conducted in 2006 – 2007 covering the urban areas of Greater Cairo. Survey sample = 9,082 households.
HBRC Residential Building Survey[45]	A survey undertaken prior to the development of the Egyptian building codes in 2003 of 115 housing units in built the five years prior to the survey.

Consequently, it is expected that a continuous process of data collection and analysis will be required to update, complement and validate existing information. This is likely to include the commissioning and undertaking of further field surveys.

3.2. Development of Archetypes

Stock modelling generally includes the consideration of a sample of houses representative of the national housing stock [21]. The segmentation of the domestic stock into a representative database is therefore essential in the estimation procedure. Archetypes are determined through the consideration of a series of building characteristics that are deemed of particular relevance for energy use, such as house typology, total floor area, the number of floors, construction materials, percentage of glazing and its frequency of occurrence in the stock. Additional attributes can also be assigned to the selected archetypes to allow for sub-sample selection based on, for example, tenure or household type.

A review of published research undertaken by Famuyibo *et al* [46] highlighted that the number of archetypes used in various stock models ranged from as few as two to several thousand, and often utilised data from actual buildings. In formulating the archetypes for EDEM, two datasets highlighted in Table 1 are particularly important - the TAPR II dataset and the CAPMAS census surveys (1996 and 2006). The Egyptian domestic building stock predominantly consists of multi-unit high rise blocks. Table 2 highlights the main characteristics of the stock based on a sample of 17,852 buildings surveyed in the TAPRII study.

Table 2 Key Characteristics of the Egyptian Domestic Building Stock [11,42]

Characteristic	Value Type	Value
Age	Average	38 yrs
Year of construction	Median	1978
Number of units	Average	6.9 units
	Median	6.0 units
Number of floors (including ground)	Average	3.9 flrs
	Median	4.0 flrs
Total surface area of building (footprint)	Average	131.6 m^2
	Median	95 m^2
Net housing area	Average	73.5 m^2
	Median	70 m^2

3.2.1. Methodology

The methodology adopted for developing the EDEM archetypes involves the following steps [46]:

1. Confirm that the TAPR II dataset is representative of the Egyptian housing stock by comparing it with the CAPMAS census surveys.
2. Utilise studies/surveys reported in literature to develop a full set of stock characteristics which impact energy use.
3. Conduct a statistical parametric analysis to identify and rank the key characteristics determining energy use which are particular to the Egyptian domestic stock.
4. Developing representative archetypes based on the prevalence of parameters which are typically present for each key characteristic.

3.2.2. Initial EDEM Archetypes

Based on a preliminary analysis of the two main databases, the stock can be disaggregated into a number of characteristics which define type, age, tenure, number of floors and unit floor area. A preliminary analysis of the main variables defined under each give an overall 13440 unique combinations for possible domestic building archetypes. Based on the prevalence of the main parameters a base group of 5 archetypes which can be considered representative of the domestic stock can be defined (Figure 4).

The archetypes (2 types of high-rise blocks, 1 low rise block, a suburban villa and a typical rural house) are based on the broad definitions defined in the two main surveys, with further information derived from the HBRC residential survey [45]. These will serve as a basis for further development of archetypes that will take place (in particular, archetypes for a high-income, low rise block and seasonal chalets prevalent in resorts). This is outlined in more details in the Future Work section of this paper.

4. Discussion and Conclusions

In addressing the current and future energy challenges in Egypt exemplified by the recent spate of blackouts, a holistic approach that integrates a variety of available technical and policy energy demand reduction options across the various socio-economic sectors should be adopted. The building sector has been identified as a key contributor to achieving energy and emissions reduction targets and an important field for the implementation of evidence-based research to inform the decision-making and policy formulation process required to ensure that these reduction targets are achieved.

A review of literature has highlighted both the key research efforts undertaken in this area and has, more importantly, identified a critical knowledge gap regarding the development of a comprehensive and flexible physics-based energy use stock model for the Egyptian domestic sector. This paper has presented a detailed and comprehensive framework for the development of such a model for the estimation of energy use and emissions of the domestic building stock– the Egyptian Domestic Energy Model (EDEM).

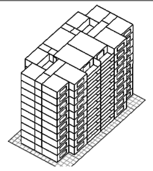
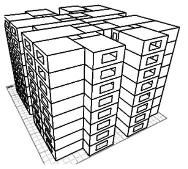
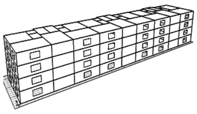
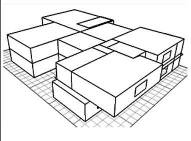
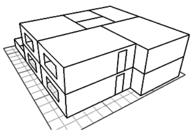
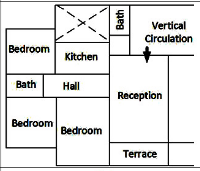
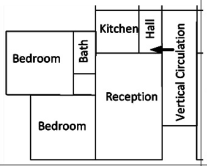
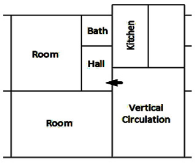
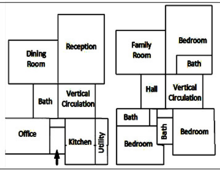
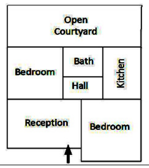
Variant	**High Income High Rise Block**	**Low Income High Rise Block**	**Low Income Low Rise Block**	**High Income Villa**	**Rural House**
Code	**HHB**	**LHB**	**LLB**	**HV**	**RH**
Unit Layout					
Unit Layout Plan	 Bath Vertical Circulation Bedroom Kitchen Bath Hall Reception Bedroom Bedroom Terrace	 Kitchen Hall Bedroom Bath Vertical Circulation Reception Bedroom	 Bath Kitchen Room Hall Room Vertical Circulation	 Dining Room Reception Family Room Bedroom Bath Bath Vertical Circulation Hall Vertical Circulation Office Kitchen Utility Bath Bedroom Bath Bedroom	 Open Courtyard Bedroom Bath Hall Kitchen Reception Bedroom
Income Group	High	Low	Low	High	Low
Location	Urban	Urban	Urban	Suburban	Rural
Occupants	Multi-Family	Multi-Family	Multi-Family	Single Family	Multi-Family
Floor Area	150m^2	90m^2	60m^2	450m^2	100m^2
No of Floors	12 floors	8 floors	4 floors	2 floors	1 or 2 floors
No of Units	2 to 3 per floor	4 per floor	6 per floor	N/A	1 per floor
Tenure	Owner-Occupied	Rented (New Law)	Owner-Occupied	Owner-Occupied	Owner-Occupied
Age band	1980-1989	Post 1999	1960-1969	Post 1999	1950-1959
Construction	Reinforced Concrete	Cement Brick	Cement Brick	Cement Brick	Silt Brick
WindowArea	>15m^2	<15m^2	<15m^2	>15m^2	<15m^2
Installed Air-Conditioning	Yes	No	No	Yes	No
Appliance Ownership	High	Low	Low	High	Low

Fig.4. EDEM Base Archetypes

The development of EDEM will help aid the understanding of the energy consumption and demand profiles, provide insight on the future of its energy demand and support a wide scale national program for the uptake of energy efficiency measures in the building sector. The work has highlighted a number of key data sources that could be used for the databases required to support the EDEM model, defined a proposed methodology for the development of representative domestic archetypes and formulated a number of initial archetypes based on the analysis of key datasets. In addition, areas of further work have been defined and the implementation of the associated tasks will be further discussed in the following section.

Finally, it should be recognised that the development of models and associated data collection involve an iterative process which is continually informed through the experience gained in undertaking the development process itself. It has been suggested that as policy requires the delivery of increasing reductions in energy demand from the built environment, more emphasis on empirical evidence is needed for robust model development to support policy formulation. A clearer sense of the uncertainty in the results and a better understanding of the extent and conditions in which models are 'wrong' are required so we can determine how 'useful' they can be for improving energy performance [47]. Consequently, further work regarding the validation of the model predictions is imperative to establishing its usefulness.

5. Future Work

The model described in this paper is an ongoing project currently in its initial stages of development. The authors intend to further develop EDEM. Further work on the model is expected to be implemented over the coming period will include the following:

5.1. *Further development and optimization of EDEM archetypes*

In addition to the development of the two remaining base archetypes, the next stage of model development will incorporate data from DEBE to refine the assumptions regarding building envelope construction materials. As more data becomes available, these preliminary archetypes can be further improved and adjusted in accordance with new findings. To complement further analysis of existing databases, the commissioning and undertaking of further field surveys is planned.

5.2. Development of model interface

While the spreadsheet interface described in this paper is expected to allow a high degree of functionality, a more user-friendly GUI will be developed to allow the more rapid input of data and increased integration with an output module.

5.3. Definition of uncertainty and calibration of model results

There are many sources of error in the model development process . It is crucial to understand both how uncertainties in the input variables propagate to the output variables via the modelling process and how the uncertainty on each output variable depends of the uncertainty on each input variable. As a result, a testing program is planned and will be documented in upcoming EDEM papers. Key testing methods proposed include sensitivity analysis (such as the Monte Carlo method to observe the impact of various model input variables and parameters upon model behaviour) validation with top-down data (e.g. energy use statistics) as well as empirical validation using monitored data from surveyed domestic buildings.

References

[1] P. Sadorsky. The impact of financial development on energy consumption in emerging economies. Energy Policy 2010;38. Pp. 2528–35.

[2] A. Eberhard,V. Foster, C. Briceño-Garmendia,F. Ouedraogo, D. Camos, M. Shkaratan. Underpowered: The State of the Power Sector in Sub-Saharan Africa 2008.

[3] R. Raslan. Performance Based Regulations: The Viability of the Modelling Approach as a Methodology for Building Energy Compliance Demonstration. PhD Thesis. University College London, 2010.

[4] JCEE &MED-ENEC. National Consultation Egypt Policies for Energy Efficiency in Buildings in Egypt Energy efficiency codes in the policy mix 2009.

[5] MOEE. Ministry of Electricity & Energy Statistics 2012.

[6] N. Kohler & W. Yang. Long-term management of building stocks. Building Research & Information 2007;35:351.

[7] C. Sjöström. Sustainable construction & performance based standards & codes 2000.

[8] A. Azis, A. Memon, I. Rahman, S. Nagapan, Q. Latif. Challenges faced by construction industry in accomplishing sustainability goals. 2012 IEEE Symposium on Business, Engineering & Industrial Applications (ISBEIA), 2012, p. 630–4.

[9] A.Hassanein & S. Adly. Small Egyptian Construction Firms: The Financing Barrier. Oxford Business &Economics Conference Program, Retrieved; 2008.

[10] S.Michel & H. Elsayed. Examples of low energy design at urban scale in Egypt. PLEA, Switzerland, Geneva 2006.

[11] CAPMAS. Central Agency for Public Mobilization & Statistics 2013.

[12] IPCC. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II & III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: IPCC; 2007.

[13] Carbon Trust. Building a Brighter Future-a Guide to Low Carbon Building Design 2005.

[14] D. ürge-Vorsatz, S. Koeppel & S. Mirasgedis. Appraisal of policy instruments for reducing buildings' CO2 emissions. Building Research & Information 2007;35:458–77.

[15] D. Crossley, M. Maloney & G.Watt. Developing Mechanisms for Promoting Demand-side Management & Energy Efficiency in Changing Electricity Businesses. Hornsby Heights: International Energy Agency; 2000.

[16] M. Grubb. Energy Policies & the Greenhouse Effect: Country Studies & Technical Options. Dartmouth Pub Co; 1991.

[17] A. Verbruggen & V.Bongaerts. Workshop documentation. SAVE 2001 Project, Bringing Energy Services to the Liberalized Market (BEST) 2003.

[18] J. Huang & J. Deringer, M. Krarti & J. Masud. The Development of Residential & Commercial Building Energy Standards for Egypt. Proc Energy Conservation Workshop in Buildings Workshop, Kuwait, 2003.

[19] J. Hensen. Energy Related Design Decisions Deserve Simulation Approach. Second Design & Decision Support Systems in Architecture & Urban Planning, 1994.

[20] B. Coffey, S. Borgeson, S. Selkowitz, J. Apte, P. Mathew & Haves P. Towards a very low-energy building stock: modelling the US commercial building sector to support policy & innovation planning. Building Research & Information 2009;37. Pp. 610–24.

[21] M. Kavgic, A.Mavrogianni, D. Mumovic, A. Summerfield, Z. Stevanovic & M. Djurovic-Petrovic. A review of bottom-up building stock models for energy consumption in the residential sector. Building & Environment 2010;45. Pp.1683–97.

[22] A. Mavrogianni. Modelling domestic space heating demand & heat wave vulnerability within the London urban heat island. PhD Thesis. University College London, 2012.

[23] IEA. Mapping the energy future: energy modelling & climate change policy. Paris, France: International Energy Agency/Organisation for Economic Co-operation & Development; 1998.

[24] L. Swan & V. Ugursal. Modeling of end-use energy consumption in the residential sector: A review of modeling techniques. Renewable & Sustainable Energy Reviews 2009;13.Pp.1819–35.

[25] J. Taylor, M. Davies & K. Lai. The Simulation of the Post Flood Drying of Dwellings in London, Kandy: 2010.

[26] R. Hitchin. Implementation of EU Directives on Energy Efficiency into the Czech Republic Review of the EPBD in Relation to Article 3: Calculation Procedures 2005.

[27] R. Busch. Modelling Building Energy Systems. In: Hunn B, editor. Fundamentals of Building Energy Dynamics, Cambridge, Mass: MIT Press; 1996.

[28] B. Anderson, P. Chapman & N. Cutland N. BREDEM-12 model description: 2001 Update. Watford, UK: Building Research Establishment; 2002.

[29] C. Dickson, J. Dunster, S. Lafferty, L. Shorrock. BREDEM: Testing monthly & seasonal versions against measurements & against detailed simulation models. Building Serv Eng Res Technol 1996;17:135–40.

[30] M. Doyle. Investigation of dynamic & steady state calculation methodologies for determination of building energy

performance in the context of the EPBD. MPhil. Dublin Institute of Technology, 2008.

[31] P. Thomas. DES 17-Building Energy Performance Simulation - a Brief Introduction 2002.

[32] S. Attia, A. Evrard & E. Gratia. Development of benchmark models for the Egyptian residential buildings sector. Applied Energy 2012;94. Pp.270–84.

[33] A. Beshara. Egypt's renewable energy activities & the need for a dedicated professional association 2010.

[34] USDOE. Building Technologies Office: EnergyPlus Energy Simulation Software. EnergyPlus Simulation Software 2013.

[35] A. Wright. Development of a building energy model for carbon reduction in the UK non-domestic stock. Proceedings of the ninth International IBPSA Conference - Building Simulation 2005, Montreal, Canada: IBPSA; 2005.

[36] LBL. Simergy - Graphical User Interface for EnergyPlus | Simulation Research Group. Simergy - Graphical User Interface for EnergyPlus | Simulation Research Group 2013.

[37] OEP/DRTPC. Energy consumption survey on the residential sector in Cairo. Development Research & Technological Planning Center. Cairo University; 1999.

[38] ECEP/DRTPC. Residential Energy Survey & Environmental Indicators in Greater Cairo. Cairo, Egypt: Energy Conservation & Environmental program at Development Research & Technological planning Center; 2001.

[39] GEF, UNDP. Energy survey & environmental indicators in the residential sector in greater Cairo. Cairo, Egypt: Energy efficiency improvement & greenhouse gas reduction project Cairo; 2003.

[40] OEP, AU. Analysis of energy consumption pattern & environmental indicators for the residential sector of Asyut city. Cairo, Egypt: Asyut University, Faculty of Engineering, Organization for Energy Planning; 2002.

[41] S. Attia & O. Wanas. The Database of Egyptian Building Envelopes (DEBE):A Database for Building Energy Simulations, Madison, Wisconsin: 2012.

[42] D. Sims, H. Kamal & D.Solomon. Housing Study For Urban Egypt. USAID; 2008.

[43] R. Struyk & I. Roman. Incidence & Determinants of Housing Upgrading in Cairo. Review of Urban & Regional Development Studies 2007;19: Pp.123–37.

[44] World Bank. Egypt - A framework for housing policy reform in urban areas in Egypt : developing a well functioning housing system & strengthening the national housing program. The World Bank; 2008.

[45] S. Michel. Residential Building Survey 2009.

[46] A. Famuyibo, A. Duffy& P.Strachan. Developing archetypes for domestic dwellings—An Irish case study. Energy & Buildings 2012;50:150–7.

[47] A. Summerfield, R. Raslan, R. Lowe, & T. Oreszczyn. How wrong & how useful are our energy simulation models for regulatory & policy development? Proceedings of the Twelfth International IBPSA Conference (BS 2011), Sydney, Australia: 2011.